High speed image techniques for construction safety net monitoring in outdoor conditions

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Abstract

The behaviour of a construction safety net and its supporting structure was monitored with a high speed camera and image processing techniques. A 75 kg cylinder was used to simulate a falling human body from the upstairs floor of a building under construction. The cylinder rolled down over a ramp until it reaches the net. The behaviour of the net and its supporting structure was analysed through the movement of the cylinder once it reaches the net. The impact was captured from a lateral side with a high speed camera working at 512 frames per second. In order to obtain the cylinder position each frame of the sequence was binarized. Through morphological image processing the contour of the cylinder was isolated from the background and with a Hough transform the presence of the circle was detected. With this, forces and accelerations applying on the net and the supporting structure have been described, together with the trajectory of the cylinder. All the experiment has been done in a real structure in outdoors location. Difficulties found in the preparation of the experiment and in extracting the final cylinder contour are described and some recommendations are giving for future implementations.

Method

- **Experimental setup**

All the experimental setup was arranged in a building structure. In order to simulate the falling body, a 75 kg cylinder is dropped from a height of 4.33 m over a 60º sloped surface until it reaches the protection system (Fig. 1). Two different protection systems were used here. One of them used a net made of textile thread net while the other is made by a steel wire mesh. The supporting structure of the protection system was common to both nets. This structure was anchored to the ground by two dead weights. For each kind of surface two experiments were made.

The movement of the cylinder was recorded by a high speed camera located in one side of the experiment. The camera used in this experiment was an AOS X-Pri, working at 512 fps with a frame resolution of 800 x 560 px. In this video sequence some simple shapes can be tracked for determinig object movements[1].

Figure 1. Experimental setup

- **Image processing algorithm**

Detection of the cylinder position consists of two basic steps. In the first step, the scene is binarized and the borders extracted. The image is cleaned in order to remove as much noise as possible. In the second step, the presence of a circular shape is detected by means of the Hough transform. In order to facilitate and accelerate the calculation, the position of the cylinder and its radius is manually estimated in the first frame. For the remaining frames of the sequence, the process is fully automatic.

After the video capture, the sequence is moved from the camera to the computer and processed off-line with Matlab. The first frame of the sequence is presented to the user and three points from the lateral side of the cylinder (a circle) must be selected by hand. From these three points we geometrically estimate the center and the radius of the circle.

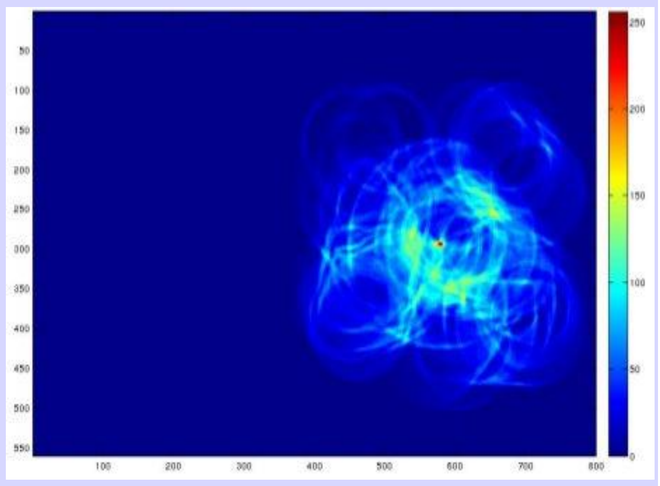

Figure 2. Hough transform

We can take the absolute difference of two consecutive frames and then multiply this difference by the original image, so only those parts belonging to it will be enhanced while the others will be strongly attenuated. The image is then cleaned through a median filtering. A Sobel filter will finally extract the borders of the image. Then, the Hough transform will search for the exact position of the circumference centre (Fig. 2). This algorithm traces circumferences that pass through a particular white pixel of the binary image, and counts how many of the pixels in the image are likely to belong to any of these circumferences.

From the first image, the algorithm runs automatically and detects the position of the cylinder at each frame (Fig. 3). After doing this process in all frames, the complete trajectory is obtained (Fig. 4).

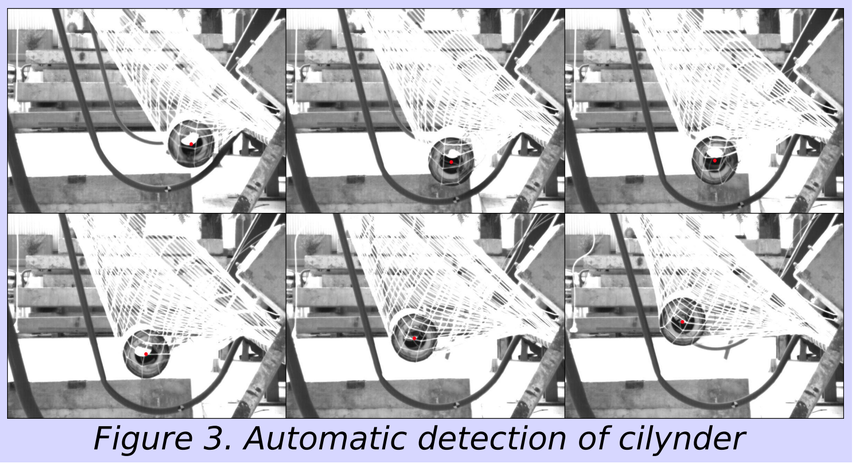

Figure 3. Automatic detection of cilynder

Results

The main results of this work are the maximum deflection of the net and the maximum deceleration suffered by the cylinder. All these results can be obtained from the cylinder trajectory. Since the cylinder diameter is known, we can calculate the px to mm conversion factor and thus obtain the real movement of the cylinder

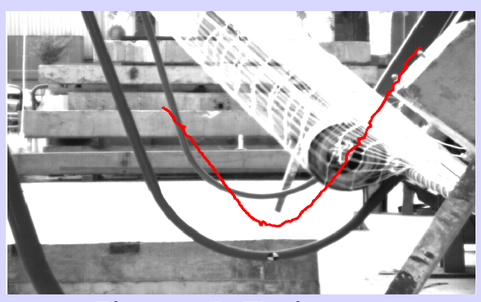

Figure 4. Trajectory

A least-squares fitting of the trajectory to a polynomial equation was done. Different degrees of the polynomial equation were used to asses the stability of the result. Second derivative of the fitting expression gives the cylinder acceleration (Fig. 5).

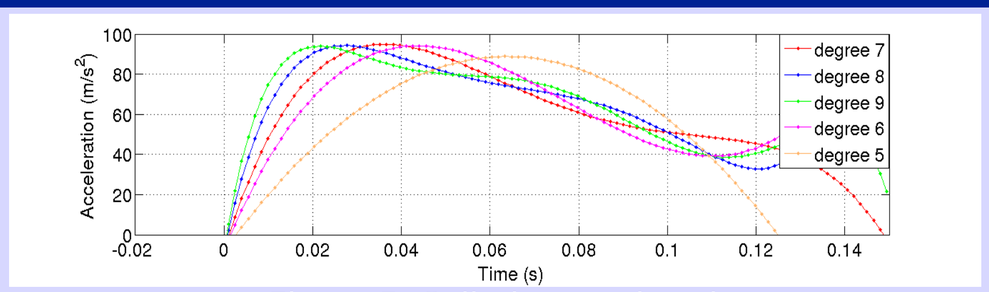

Figure 5. Cylinder acceleration

Finally, it was found that steel wire mesh fulfills the recommendation of a minimum deflection of 200 mm but with a deceleration of 30 g, too much for a human body[2]. Relatively safe values of acceleration were obtained for the textile thread net, but with deflections between 2.5 and 3.5 times higher than the minimum values required by European Code [3].

References

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[2] Voshell, M. “High acceleration and the human body”, at http://csel.eng.ohio-state.edu/voshell/gforce.pdf last seen in 03-16-2012

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